Storm-driven maritime dispersal of prickly pear cacti (*Opuntia* species)

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INTRODUCTION

The majority of *Opuntia* species in the eastern US are found in the Atlantic and Gulf Coastal Plains. These species tend to occur in soils with higher amounts of sand which provide for more xeric environments. This presumably lessens interspecific competition, which is important for these slow-growing cacti. Several species of *Opuntia* (e.g., *O. humifusa* (Raf.) Raf., *O. pusilla* (Haw.) Haw., and *O. stricta* (Haw.) Haw.) are found in coastal habitats from North Carolina to eastern Texas (Benson 1982, Pinkava 2002). These species are particularly abundant on the barrier islands along the Gulf Coasts of Mississippi, Alabama, and Florida.

Opuntia are widely known to be dispersed vegetatively by disarticulation of cladodes from the parent plant (Benson 1982, Rebman & Pinkava 2001, Pimienta-Barrios & Castillo 2002). For example, *Opuntia pusilla* is renowned for its disarticulating cladodes that are armed with retrorsely barbed spines, which easily pierce fur, skin, and other surfaces (Radford et al. 1968, Benson 1982; **Fig. 1**). Accordingly, they can be dispersed effectively by animals passing through populations of these plants (Pimienta-Barrios & Castillo 2002). These vegetative propagules root readily and form new plants in suitable habitats (**Fig. 2**). Such vegetative propagation can be one of the main means of reproduction for some *Opuntia* species (Benson 1982, Frego & Staniforth 1985, Rebman & Pinkava 2001, Pimienta-Barrios & del Castillo 2002, Reyes-Agüero et al. 2006).

Because of the ease with which vegetative fragments of *Opuntia* regenerate, it is likely that storms in coastal areas dislodge cladodes that could serve as dispersal units in long-distance maritime transport for establishment of new populations. The present work aimed to document one potential example of such dispersal associated with a major hurricane along the US Gulf Coast.

PLANT SURVEYS

Initial plant surveys were conducted during summer 2004 at Greenwood Island in Jackson County, Mississippi. Greenwood Island is a peninsula adjacent to Bayou Cassotte, just west of the Grand Bay National Estuarine Research Reserve and Grand Bay National Wildlife Refuge (**Fig. 3**).

The periphery of Greenwood Island grades into salt marsh, which is the most common vegetation cover in the area. A portion of the interior of Greenwood Island presently is covered by spoils from dredging operations and mainland expansion from the commercial occupants of the northeastern area of the peninsula. The peninsula is surrounded by an earthen levee approximately 4.3m (14ft) in height.

No *Opuntia* species were seen growing in the surveyed area during 2004. The dominant vegetation on the higher areas (oyster shell middens) consisted of *Quercus viginiana, Solidago sempervirens, Baccharis halimifolia, Cissus trifoliata, Ampelopsis arborea*, and *Iva frutescens*. Species more common to the peripheral salt marsh were *Juncus roemarianus, Solidago sempervirens, Borrichia frutescens*, and *Ipomoea sagittata.*

On January 14, 2006, 4.5 months after Hurricane Katrina, a second survey was conducted of the same area. Most of the vegetation had been compressed, or removed, by the force of the storm, and much of the previously surveyed area was occupied by bare soil.

However, an abundance of disarticulated *Opuntia* cladodes were observed, which appeared to have been deposited on the site from Hurricane Katrina. Both *Opuntia humifusa* and *O. stricta* were observed. Generally, these plants consisted of individual pads, but occasionally 2-3 joined cladodes or whole plants were noted.

Figure 1. *Opuntia pusilla* clinging to clothing, illustrating ease of vegetative dispersal in this species.

Figure 2. *Opuntia* cladodes frequently are encountered in wrack along shorelines. Left and center are *Opuntia humifusa* observed in wrack on Horn Island, MS. Far right is an *O. stricta* plant that established in wrack deposited on an oyster shell midden in Grand Bay, MS.

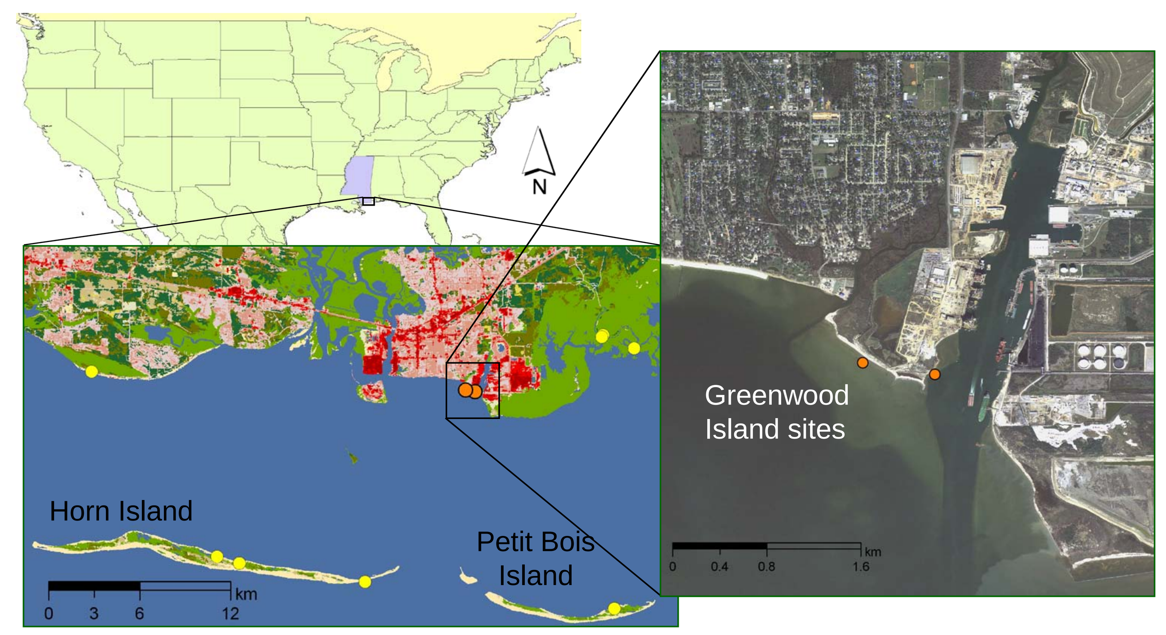

Figure 3. Aerial photograph on the right shows location of Greenwood Island vegetation surveys (orange points) at the base of the earthen levee.

Middle panel shows location of Greenwood Island, relative to known populations of *Opuntia* at the time Hurricane Katrina made landfall (yellow points).

The points east of Greenwood Island are *Opuntia* on Grand Bay, MS oyster shell middens.

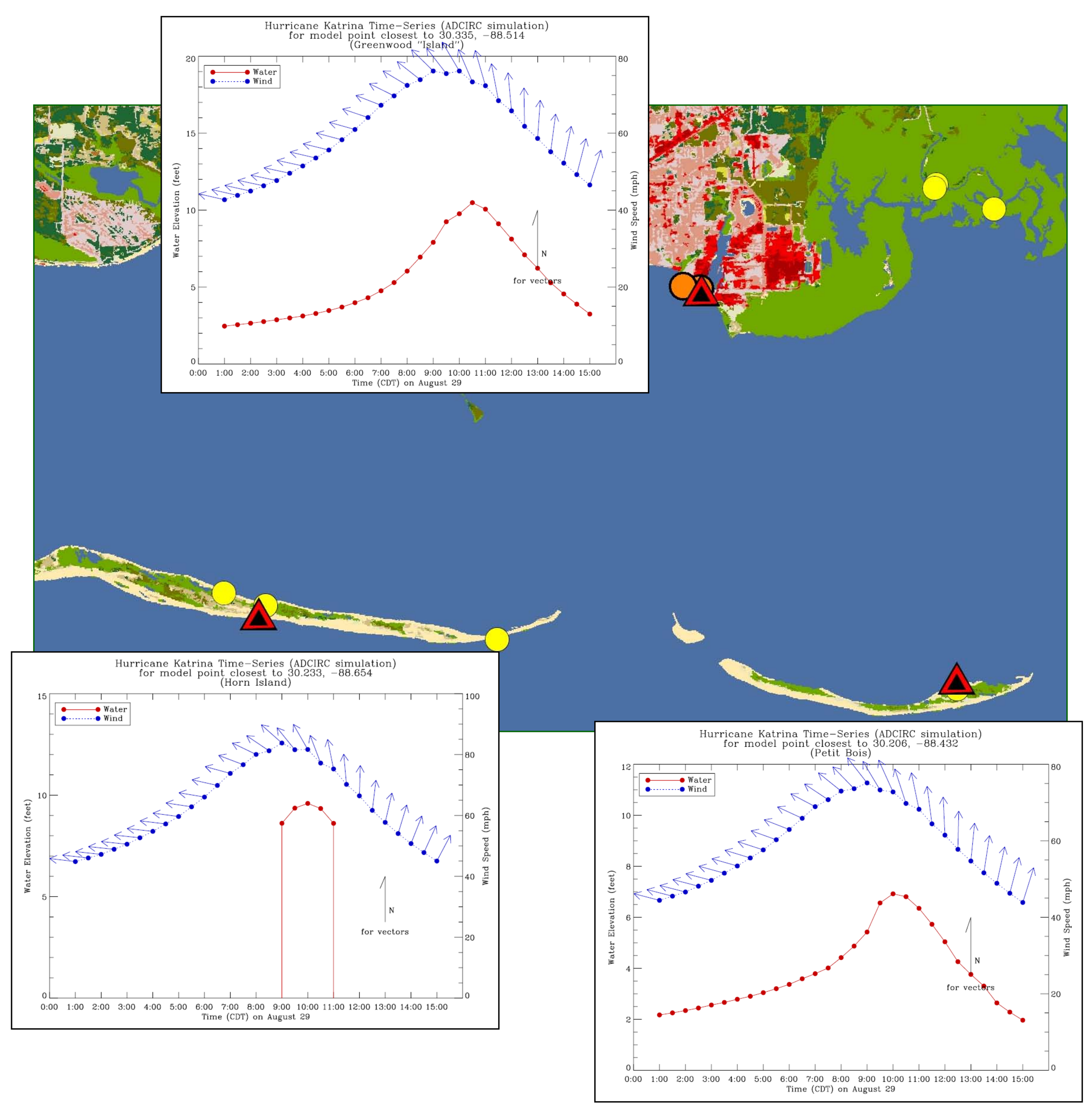

Figure 4. Water elevation (feet) due to Hurricane Katrina's storm surge as simulated by the ADvanced CIRCulation (ADCIRC) model at the locations denoted by red triangles on Horn Island, Petit Bois Island, and the Greenwood Island peninsula. Also shown are their observed wind speed (mph) and direction. The winds originally were from the east-southeast at midnight on 29 August, then shifted to the south by the afternoon. Tropical-storm force sustained winds began at 10PM 28 August, and peaked at 9AM 29 August. Wind gusts above 100 mph began at 6AM 29 August (not shown). ADCIRC shows the surge peaked between 10AM and 11PM. The observed surge based on high water marks was between 17.0 and 17.4 feet (the model has a low bias).

Figure 5. Entire *Opuntia humifusa* plant trapped in a slash pine (Pinus elliotii) on Horn Island, MS (November 26, 2006). Note in the inset photo the new cladode (middle, right of large basal stem) that appeared to have been produced while the plant was suspended from the tree.

METEOROLOGICAL DATA

Hurricane Katrina was an unusually large major hurricane, resulting in a prolonged period of damaging winds and a 17-foot storm surge in the Greenwood Island area on 27 August 2005. The sustained winds peaked at 88 mph with gusts up to 105 mph. According to an anemometer at Ingalls Shipyard, winds gusts over 100 mph began at 6AM, associated with a possible outer eyewall. The inner eyewall made landfall between 9AM and 10AM as well as the maximum sustained winds. Time series of the wind data were obtained from the Hurricane Research Division, and are shown in **Fig. 4**.

To assess the water elevation evolution, the Advanced CIRCulation (ADCIRC) hydrodynamic model (Luettich and Westerink 2007) was used to simulate Katrina's storm surge, and a time series was computed (**Fig. 4**) The model underpredicts the water height, but correctly shows the surge peaking between 10AM and 11AM. In addition wave heights of 5-10 feet at the islands, and about 2-3 feet at the levee system, were superimposed on the surge.

The wind direction (and roughly the water current as well) started out from the east-southeast during the night, then shifted to the southwest in the afternoon. This suggest either the wind or the surge transported broken cactus from the islands to this mainland region. Either mechanism would have provided the 200 N of force necessary to break or dislodge a typical sized cladode of *O. humifusa* (approx. 0.01cm^2 surface area). This would translate to the equivalent of a 20kg mass applied to the cladode, which is more than sufficient for disarticulation of some of the most fibrous *Opuntia* species (Bobich and Nobel 2001). Future trajectory calculations will be performed to test this hypothesis.

CONCLUSIONS

Maximum wind speeds and the forces they created on the barrier islands were of more than adequate strength to have dislodged *Opuntia* cladodes. In fact, entire plants were observed to have been dislodged from the soil and deposited elsewhere on the islands (**Fig. 5**).

Wind direction data also suggest a high likelihood that the *Opuntia* that colonized the Greenwood Island peninsula could have originated on Petit Bois Island, where *Opuntia* were known to exist approximately 16km to the southeast (**Fig. 4**).

These results lend support to the hypothesis that storms and maritime transport of *Opuntia* could contribute to long-distance dispersal of these plants – as well as long-distance dispersal of invertebrate herbivores, such as *Cactoblastis* that may inhabit cladodes at the time of transport.

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